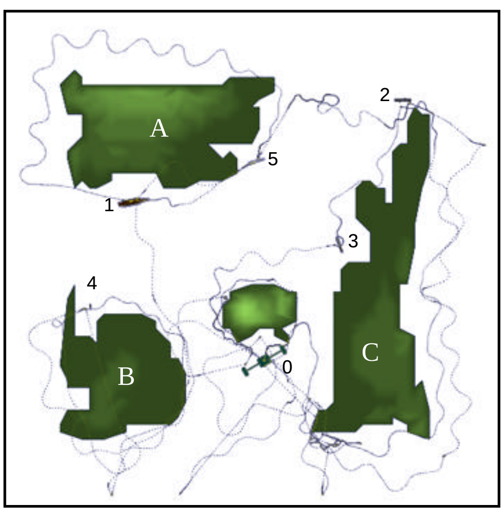
Chapter 9 Discussion

The disorientation most commonly associated with the control treatment is evident in a number of ways. A typical path chart of the route followed during an average control treatment shows significant confusion and a general inability to organize the space (See Figure 9-1). In this example, a coastline following method was used. The path shows that this subject traversed each land mass multiple times with a single thread joining A to the others. There is no point in this environment from which A can be seen simultaneously with B or C. Consequently, most of the search was confined to familiar areas near the home target. This subject drew a map which shows a basic inability to extract spatial information from the space.



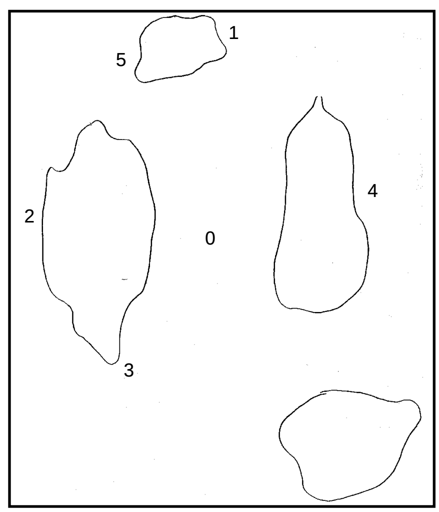


Figure 9-1 A typical control treatment path and its associated map drawing. [Subject 3, Control]

The presence of the radial grid was shown to significantly improve directional accuracy. Map sketches of both the grid and map/grid treatments were more accurate in target placement than the control and map treatments. This is shown in Figure 9-2. This subject used an area search method in the grid treatment. The map shows that although the subject placed the targets very accurately, the land mass structure is incorrect. Due to the geocentric view provided, the map and map/grid treatments showed the most accurate land forms on the map sketching exercise.

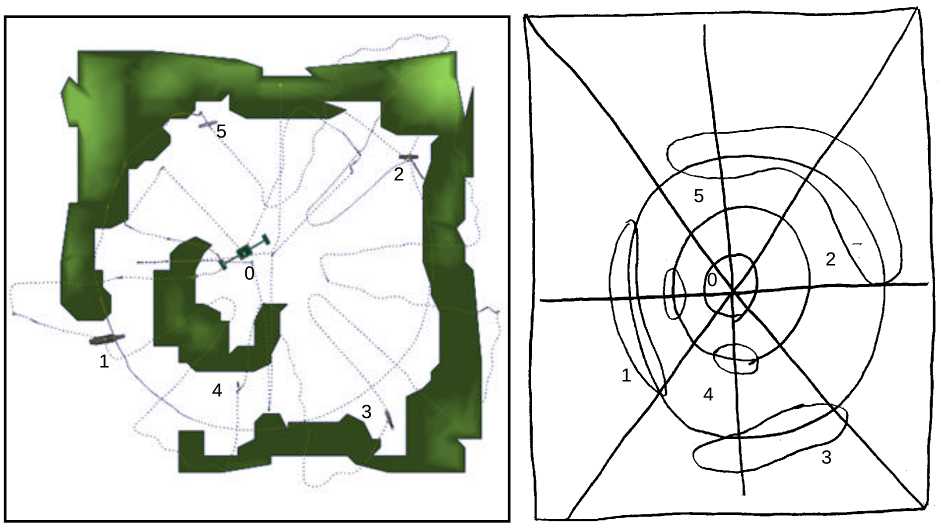


Figure 9-2 A grid treatment showing the patterns of search confined to sequential areas of the grid. [Subject 4, Grid]

The fact that reasonable cognitive representations were discerned from the data (See Figure8-3 on page149), even in the control treatment indicates that structure was imposed on the environments whether or not it was supported by the environment itself. This structure is a necessary precondition to execution of a searching task. Those subjects who did not conceptually organize the environment were unable to conduct an efficient search and in many cases, did not successfully complete the task.

Thorndyke describes survey knowledge in part as configurational knowledge, often acquired via a map, allowing short-cuts and the ability to infer new paths. The optimizations to the control treatment search methods observed in the map treatment illustrate this point exactly. The path shown in Figure 9-3A is cut short around target 5 rather than cross a land mass of known shape. This path can be compared to Figure 9-3B which shows the same search technique used in the control treatment. The subject is unsure of the shape and size of the land masses and therefore does not deviate from the pattern.

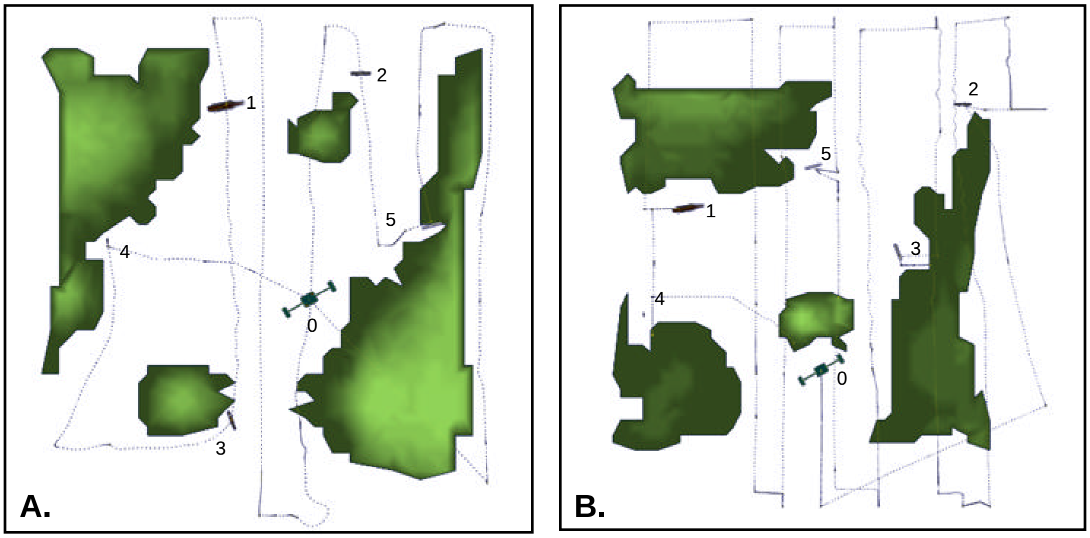


Figure 9-3 A. A map treatment illustrating the lawnmower method of search with optimizations. B. The same method in a control treatment. [Subject 4]

Behavior observed during all four treatments indicates that organizational structure and restriction of movement are an essential part of navigation. Subjects were uncomfortable with completely free and unrestricted movement in sparsely populated space because it led to disorientation much of the time. When the grid was added, this discomfort subsided as subjects found structure to guide and direct their search and consequently, avoid disorientation. The importance of paths as described by Lynch indicates that in virtual and physical spaces alike, navigators need structured movement for effective navigation and spatial knowledge acquisition. This should not be interpreted as a recommendation of rigid movement restriction in virtual worlds. A lack of freedom in movement and choice inhibits exploration. Rather, the results advocate the augmentation of large virtual worlds with directional cues and a simple, well-defined structure that facilitates subjects' construction of their own paths.

The frequent use of dead reckoning across treatments was not an anticipated behavior. Effective use of this technique requires three necessary components:

- the current position
- the direction of movement, and
- the velocity of movement.

The effectiveness of the technique is much improved if there are reference points within view of the path of travel which can be used as “checkpoints” marking progress along the way. This was only the case when the grid was present. From the relative success of dead reckoning in the non-grid treatments a reasonable conclusion is that the frame rate (≥15 frames/second) and visual cues (specifically the sea texture) provided enough feedback to maintain a consistent estimation of velocity. The technique is further encouraged by the method of movement since the subject must always look in the direction of movement.

Factor to Factor Associations

Correlation between variables was determined using a Pearson product-moment correlation coefficient. For each r value computed in the matrix, its significance level was determined using the following formula:

$$t = r\sqrt{\frac{(N-2)}{(1-r^2)}}$$

where r is the Pearson correlation coefficient

N is the number of correlation pairs (10 in this case - same as the number of subjects)

t is the t-Test value found by a table look-up, and

df (degrees of freedom) is N-2 or 8

For this analysis:

r=0.7 : p= 0.05

r=0.76 : p=0.01

r=0.9 : p=0.001

The correlation charts shown in this section are those with r values at or above 0.65 and consequently, at p=0.05 or better. Discussion will begin with associations involving the cognitive factors examinations and will conclude with associations between the wayfinding factors described in detail in Chapter 7.

Cognitive Factor Associations

The visualization factor of the cognitive examinations is thought to be an expanded version of the spatial orientation factor (Ekstrom, et al., 1976). This is supported by the data here as they are highly correlated. Both of these factors require a mental manipulation of a shape. See Figure 9-4.

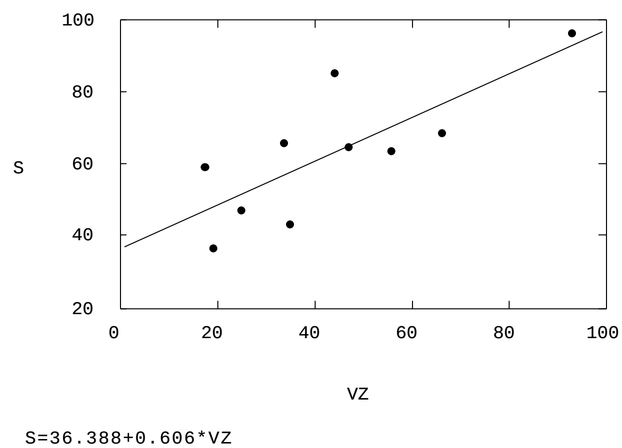
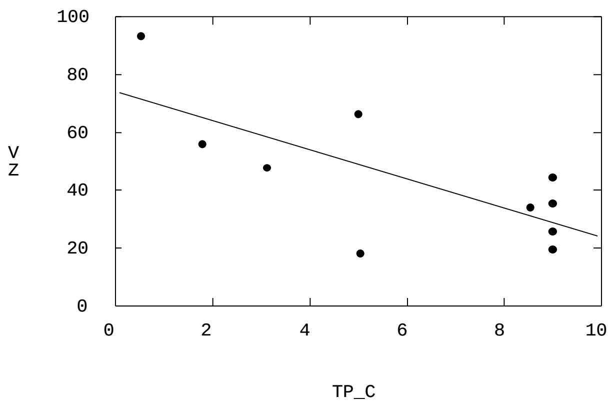


Figure 9-4 Spatial Orientation (S) to Visualization (VZ)
r=0.774

Subjects who scored highly in the visualization factor tended to execute the primed search in the control treatment with greater precision and speed than those who scored poorly. The ability of these subjects to mentally manipulate an image probably was instrumental in avoiding disorientation. Subjects who scored poorly on the visualization factor are clustered around the 10 minute mark on the primed search. See Figure 9-5.

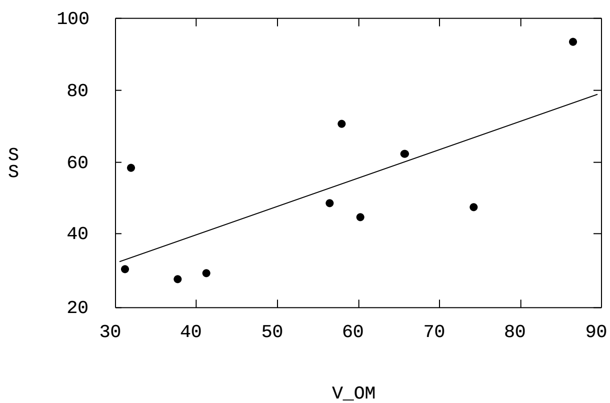
Subjects who scored highly on the spatial scanning factor tended to move at a higher velocity in the map/grid treatment than those who scored poorly. The ability of these subjects to extract the essential information from the complex visual field allowed them to move more quickly without missing targets. See Figure 9-6.

Those subjects who scored highly on the spatial scanning factor tended to draw better land masses on the map sketching exercise than those who scored poorly. Again, the ability to extract information useful to navigation and to incorporate that information into a



VZ=73.991 -5.048*TP_C

Figure 9-5 Visualization (VZ) to Primed Search Time: Control Treatment (TP_C) r=-0.723



SS=8.670+0.783*V_OM

Figure 9-6 Spatial Scanning (SS) to Average Velocity: Map/Grid Treatment (V_OM) r=0.699

cognitive representation is necessary for successful and efficient completion of the task. See Figure 9-7.

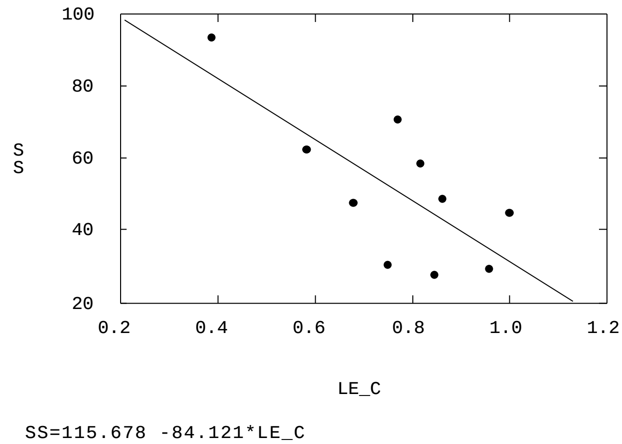


Figure 9-7 Spatial Scanning (SS) to Map Land Error: Control Treatment (LE_C) r=-0.735

Wayfinding Factor Associations

Subjects with relatively low naive search times on the map treatment tended to exhibit the same level of performance in the map/grid treatment. There are two clusters of subjects with a single outlier all showing a general positive trend. In many cases, the map was not used differently between the two treatments. As described in Chapter 8, several different behaviors were often exhibited on each trial. However, these differences are not seen here. See Figure 9-8.

There is a negative correlation between naive search time on the map and map/grid treatments and map distance error in the control treatment. Subjects with high naive search times using the map tended to approximate distance on the control treatment maps better than those who had lower search times. This is a confusing relationship. The wayfinding principles do not make any predictions related to this phenomenon. A speculative theory is that the subject pool was divided as to their primary purpose during task execution; some subjects may have been trying to make as few map errors as possible and others may have been trying to complete the task as quickly as possible. Both were given in the instructions as being important but neither was given priority. Subjects with high naive search times in

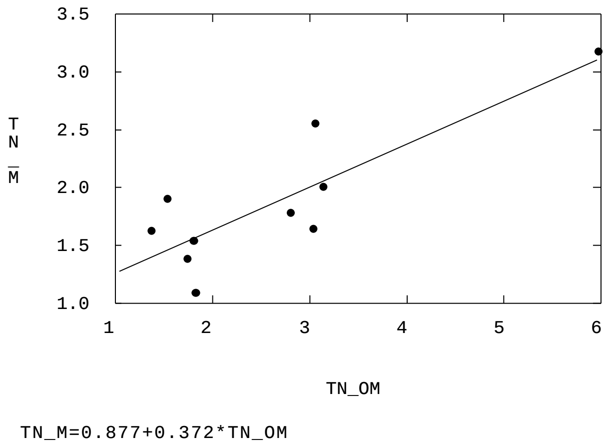
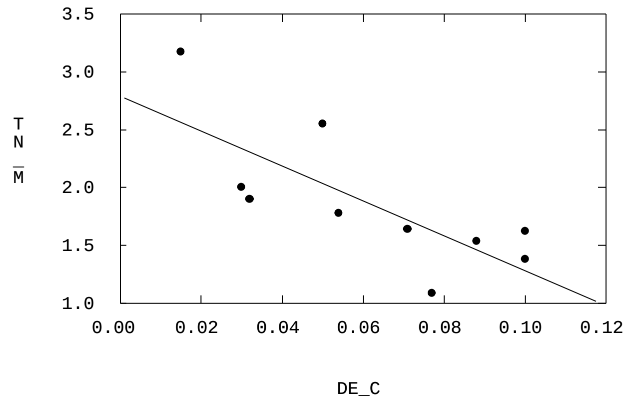


Figure 9-8 Average Naive Search Time: Map Treatment (TN_M) to Average Naive Search Time: Map/Grid Treatment (TN_OM) r=0.841

the map treatments may have intended to make as few map errors as possible and consequently, their times were higher. This does not explain, however, why such a correlation was not found between naive search times in the control treatment and map distance error in the control treatment. See Figure 9-9 and Figure 9-9.

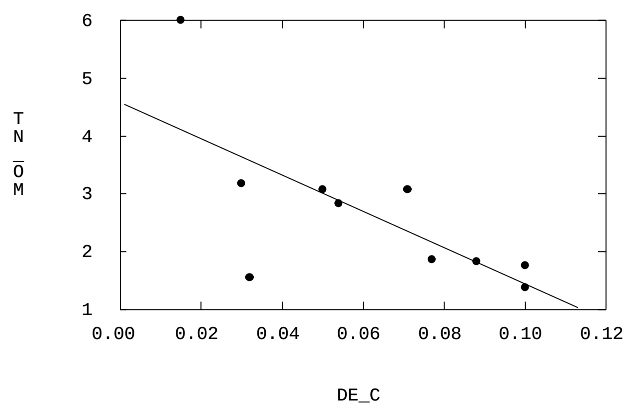
There is a positive relationship between distance travelled in the control treatment and map direction error in the control treatment. The greater the distance travelled, the higher the error measured. This indicates that the subjects who travelled the furthest tended to do so because of disorientation and consequently, their ability to accurately place targets on the map was diminished. See Figure 9-9.

Subjects who searched larger portions of the control treatment environment drew more accurate land representations on the map exercise. In many cases, subjects became so disoriented, they had no way of determining what parts of the environment had been seen previously. Consequently, large tracts of space went unsearched. And as would be expected, these subjects drew poor maps representing the space. Those subjects who constructed an organized search covering more of the environment were better able to draw the land masses in the world. See Figure 9-9.



TN_M=2.797 -15.181*DE_C

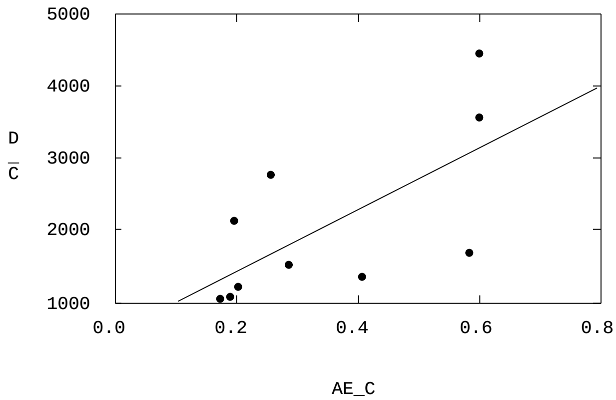
Figure 9-9 Average Naive Search Time: Map Treatment (TN_M) to Map Distance Error: Control Treatment (DE_C) r=-0.762



TN_OM=4.583 -31.461*DE_C

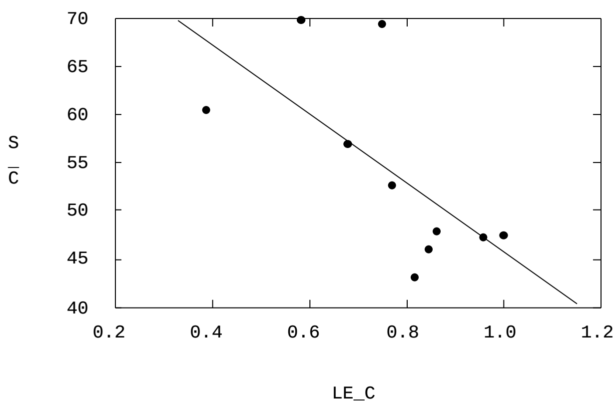
Figure 9-10 Average Naive Search Time: Map/Grid Treatment (TN_OM) to Map Distance Error: Control Treatment (DE_C) r=-0.699

There is a correlation between the average velocity in the control treatment and the average velocity in the grid treatment indicating that the absence of the map caused subjects to move at a different speed than they would otherwise. Many subjects conceptually



D_C=579.354+4271.147*AE_C

Figure 9-11 Distance Travelled: Control Treatment (D_C) to Map Direction Error: Control Treatment (AE_C) r=0.669



S_C=81.469 -35.799*LE_C

Figure 9-12 Percent of the Environment Viewed: Control Treatment (S_C) to Map Land Error: Control Treatment (LE_C) r=-0.667

treated the trials as either egocentric navigation (control and grid) or geocentric navigation (map or map/grid). See Figure 9-13.

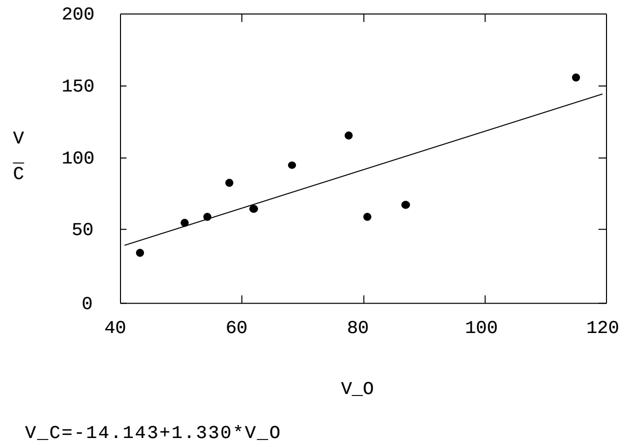


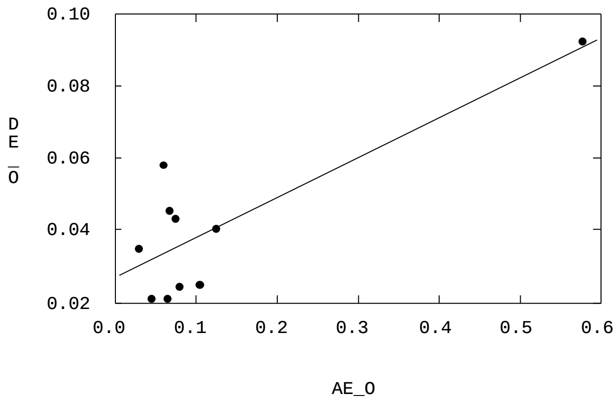
Figure 9-13 Average Velocity: Control Treatment (V_C) to Average Velocity: Grid Treatment (V_O) r=0.798

Although the relative difference between map direction errors was shown to be significantly higher than map distance errors in general (See Map Distance Error on page 125), the two are shown here to be correlated in both the grid and map/grid treatments. Subjects who estimated distance well also estimated direction well. This gives further support to the effectiveness of the grid. Not only was it shown to improve direction estimation ability in general, but it also had some effect on distance estimation. In both treatments there are one or two outliers, but the general trend holds. See Figure 9-14 and Figure 9-15.

Cognitive Map Orientation

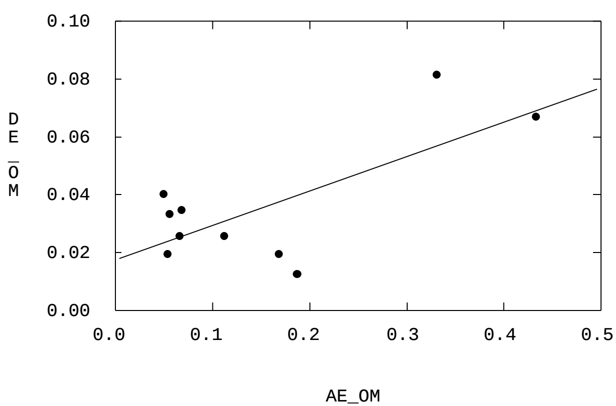
One of the objectives of the design principles was to help construct an orientation independent cognitive representation of the environment. This section will review the results and comment on whether or not this objective has been achieved.

The data presented in Table 8-1 on page 140 shows the orientation of the drawn maps in relation to the actual environment. The treatment with the greatest number of world aligned maps is the control treatment. Although each of the three other treatments has fewer aligned maps, both the grid and map/grid treatments had the fewest. Taken for face



DE_O=0.027+0.111*AE_O

Figure 9-14 Map Distance Error: Grid Treatment (DE_O) to Map Direction Error: Grid Treatment (AE_O) r=0.820



DE_OM=0.017+0.119*AE_OM

Figure 9-15 Map Distance Error: Map/Grid Treatment (DE_OM) to Map Direction Error: Map/Grid Treatment (AE_OM) r=0.711

value, this could indicate that the existence of the navigation cues and tools tended to allow subjects' cognitive representations to be more flexible. However, this data alone is far too weak to draw this conclusion.

As each trial would begin, the subject would acquire orientation by some method (See the GOMS analysis for the acquire-orientation subtask in Chapter 8). There is no magic to choosing the set-bearing-default-method which would align the mental representation with the environment. Furthermore, choosing other methods could, by mere coincidence (often a 25% probability because there are four edges to each world), end in the same result. Although the data shown here is encouraging, it is inconclusive and requires further study.

Woulda, Coulda, Shoulda

Could the clock be turned back a year to when the experimental design was first taking shape, a few things would have been done differently. In designing the environments, one of the five targets should have been placed further out in open space so that it could not be found by the edge-following-method of search. With the targets so close to the coast, not only was this method made too effective, but the heuristic-method was even better. Although subjects were never told how the targets had been positioned, several of them seemed to draw the correct conclusion. Placing one target in the open sea would have allowed post trial analysis to determine whether an exhaustive search had been performed (or at least attempted).

The length of time required to complete both the cognitive factors examinations and the wayfinding tasks was too long. It is difficult to keep a subject's attention for two $1\frac{1}{2}$ hour sessions even if they are separated by a day. The task could have been simplified by lowering the number of targets to be located and possibly by making the environments slightly smaller.

The movement metaphor was chosen for its simplicity. However, the combination of this method with the map caused unforeseen problems. The map lies below the viewpoint. As subjects looked at the map while moving, they would immediately descend to the minimum altitude. Either a different metaphor should have been used or vertical movement could have been eliminated altogether.

The subject pool was limited by the location of the laboratory. Nevertheless, this had an adverse effect on the experiment. Although the gender of subjects was evenly divided, there were no non-technical subjects included. This is most likely the cause for not finding the expected gender effects, even in cognitive factors scores. In any case, the population sample used was certainly not random.

Lastly, concerning the map drawing exercise, the most obvious mistake was having subjects start with a blank sheet of typing paper. Typing paper is not square — the worlds are. Subjects tend to want to use the whole space and consequently they distort their drawing. The actual map drawing method is also suspect. In order to get a better picture of what is known and not known, a knowledge elicitation method might precede the map drawing exercise. Subjects would be asked questions about paths between targets, directions, and distances. This could also minimize the problem of differentiating between a spatial error and a memory error. When a subject writes the wrong target number at a correct target location, is it because an error was made in spatial judgement or simply that the target number was forgotten? The method used in this experiment can’t tell them apart.